

Evaluation of Carbon Composite Overwrap Pressure Vessels Fabricated Using Ionic Liquid Epoxies

Completed Technology Project (2014 - 2015)



Project Introduction

In terms of "Innovation" this is a unique epoxy with unique properties, and NASA co-holds the patent. This epoxy is being exclusively formulated for cryogenic use. Utilizing storage tanks fabricated from fiber reinforced polymeric composites for storing cryogenic fluids such as liquid oxygen and liquid hydrogen under pressure is of great interest to NASA. In particular, their high strength to weight ratio gives them a clear advantage over strictly aluminum alloy components; a 20-40% weight reduction can also be expected. Unfortunately such composites, especially at cryogenic temperatures, develop stiffness that diminishes the desired toughness; this promotes delamination and crack growth which leads to leaking of the fuel component; this detriment is exacerbated if the component is cycled between room and cryogenic temperatures. The work proposed here intends to eliminate that concern by utilizing a unique, and patented, ionic liquid (IL) epoxy. Our novel, to date, results supporting that supposition include:

- A viable means to synthesize high-quality ionic liquid epoxy monomer has been established.
- Nano-scale Core-Shell-Rubber (CSR) particles designed to toughen polymers have been successfully and uniformly incorporated into the epoxy matrix.
- Shock cycling of the epoxy between room (RT) and Liquid Nitrogen (LN2) temperatures, with and without CSR, does not appreciably affect the fracture energy at RT establishing that micro-cracking does not develop in the samples.
- Testing shows that adding CSR particles improve toughness and strength at RT and LN2 temperatures.
- Measurements of the epoxy Coefficient of Thermal Expansion from cryogenic to room temperature is very favorable at 35 ppm which places it amongst the lowest of the common polymers.
- CSR increased the glass transition temperature (0% CSR = 61.5°; 8.8% CSR = 95.5°C) allowing a higher working range.
- Carbon-fiber test articles utilizing CSR containing epoxy have been made and show no cracking or delamination when repeatedly cycled in LN2. Relevant test results show improvements over commercial products at both room and LN2 temperatures. Slight additions of CSR significantly increases the impact toughness which appears maximized near an 8.8% addition. Considerable improvements were also noted here at both room and LN2 temperatures. It was also noted that shocking the samples between room and LN2 temperatures, up to 10 times before testing, had no obvious effect in diminishing properties, i.e. no induced micro-cracking. Earlier, it had been shown that a carbon fiber composite cylinder fabricated with the ionic liquid epoxy performed better at room and LN2 temperatures than the commercially used Hexcel®. We have since successfully made some carbon fiber layups utilizing CSR containing epoxy for preliminary examination and testing. Composite integrity was maintained on these layups with no separation, delamination, or cracking. Finally, ionic liquids have a number of additional advantages as a base for epoxy resins. Their extremely low vapor pressures, good temperature stability, and low flammability further enhance their use for NASA deep space, cryogenic, applications. They have a comparatively "greener" manufacturing process than their counterparts. Low permeability to



Carbon Fiber-Overwrapped Pressure Vessels (COPV) Manufactured Using Commercial (left) and Ionic Liquid (right) Epoxies

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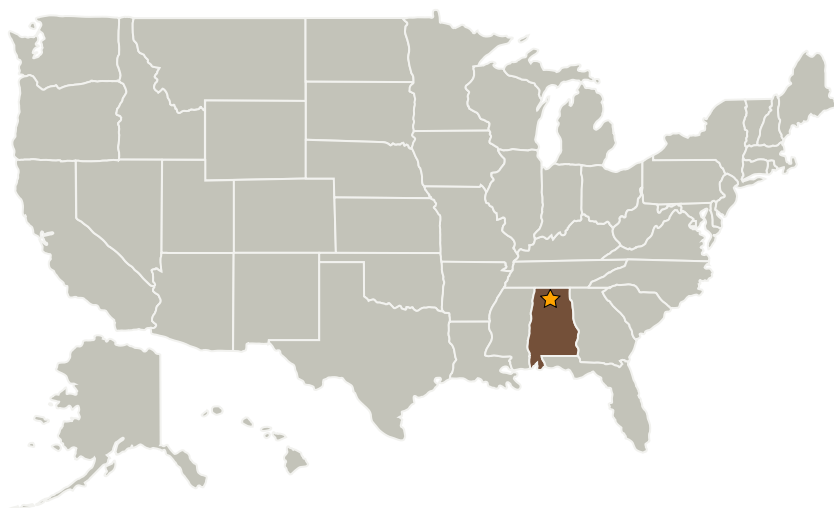


hydrogen, and trivial moisture uptake after several days of submersion in salt water was also established. The epoxy has also demonstrated strong binding to aluminum. In short, ionic liquid based epoxies and composites are ideally suited to meet challenges associated with achieving NASA's space exploration goals.

Anticipated Benefits

N/A

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★ Marshall Space Flight Center (MSFC)	Lead Organization	NASA Center	Huntsville, Alabama
AZ Technology, Inc.	Supporting Organization	Industry Veteran-Owned Small Business (VOSB), Women-Owned Small Business (WOSB)	Huntsville, Alabama

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Marshall Space Flight Center (MSFC)

Responsible Program:

Center Innovation Fund: MSFC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

John W Dankanich

Project Manager:

Andrew Keys

Principal Investigator:

Richard N Grugel

Co-Investigators:

William F Kaukler
Chad Hastings
Ellen M Rabenberg

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Primary U.S. Work Locations

Alabama

Images



Grugel - 1

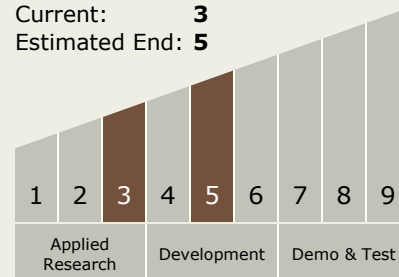
Carbon Fiber-Overwrapped
Pressure Vessels (COPV)
Manufactured Using Commercial
(left) and Ionic Liquid (right)
Epoxies
(<https://techport.nasa.gov/image/5037>)

Project Website:

<https://www.nasa.gov/directorates/spacetech/home/index.html>

Technology Maturity (TRL)

Start: **3**
Current: **3**
Estimated End: **5**



Technology Areas

Primary:

- TX13 Ground, Test, and Surface Systems
 - └ TX13.1 Infrastructure Optimization
 - └ TX13.1.1 Natural and Induced Environment Characterization and Mitigation